MOISTURE MIGRATION DURING A TEMPERING TIME AFTER THE HEAT TREATMENT STEP IN YERBA MATÉ PROCESSING

M.E. SCHMALKO, N.N. LOVERA and G.C. KOLOMIEJEC

FCEQyN- Universidad Nacional de Misiones-Felix de Azara 1552 – 3300 – Posadas - Argentina
mesh@fceqyn.unam.edu.ar

***Abstract* - The aim of this research was to study the effect of applying a tempering time to the branches of yerba maté after the heat treatment stage (or sapecado). Assays were carried out in three industrial producers of Misiones Argentina. Branches were obtained from the sapecador outlet and then, they were put in rest in order to form a bed. First, moisture content of leaves and twigs, separately, and then losses of mass of whole branches were measured. When the branches were put in rest in a bed during 30 min, 8.60 kg of water/100 kg of dry matter were transferred from the twigs to the leaves and 5.17 kg of water/ 100 kg of dry matter were lost by evaporation.**

***Key words*- yerba maté, tempering, moisture, migration.**

I. INTRODUCTION

Yerba maté (*Ilex paraguarienses* Saint Hilaire) processing consists of four stages called sapecado, drying, grinding and seasoning. Generally, the first three stages are carried out in industrial factories located near the plantation.

When the branches are collected, they are cut by hand and quickly carried in order to be processed. At the reception, a wide variation in weights and forms of branches can be observed. These variations are in weight (between 5 and 100 g), shape (with or without sub-ramifications) and length (between 30 and 60 cm) (Crotti *et al.*, 2002). Once received, they are put in a yard and they are introduced into the sapecador.

In the sapecado stage, enzymes producing browning in leaves are inactivated. The equipment consists of a cylinder that rotates at low revolution (about 10 rpm). Branches are fed in the extreme where the wood is burning. They pass through the flame between 1 and 3 times, receiving heat by radiation and convection. According to this, different branches can receive different heat treatments and loss different quantities of water. After that, the burning gases and the branches move to the output extreme in a parallel flux. Temperature of the air in the inlet extreme reaches about 350-400ºC, while at the outlet extreme it is above 100ºC (Peralta and Schmalko, 2007).

Initial moisture content of leaves and twigs are very similar (about 60%, wet basis), but at the outlet of the sapecador, the differences are high. In leaves, mean value is about 20% (wb) and in twigs, about 55% (wb) (Schmalko and Alzamora, 2001). Ratio between surface area/weight in leaves is 3 or more times greater than twigs. So, heat and mass transfer in leaves is greater than twigs and that is why losses of water are higher in leaves. Moroever, water diffusion coefficient in leaves are higher than in twigs (Schmalko *et al.*, 1996).

Alfalfa is dried as whole branches in rotary dryers, similar to yerba maté. A similar moisture gradient is generated between the stems and leaves (Arinze *et al.*, 2003; Arinze *et al.*, 2007; Moore and Cilanski, 1992; Patil *et al.*, 1992). In order to avoid excess in drying, the dried leaves are separated from the stems by dragging forces in order to have a minor residence time. Consequently, the dryer efficiency becomes higher as the solid flux is increased.

A similar technology could be applied to yerba maté processing. But these changes would modify the types of dryers used now by the industrial producers. These changes could be very expensive. So, other alternatives should be studied.

Intermittent drying (drying with tempering times) is applied to some foods in order to redistribute their internal moisture gradient. An improvement of product quality and energy saves is obtained. It has been used in rice drying (Li *et al.*, 2003; Mabamba and Yabés, 2005; Nishiyama *et al.*, 2006; Shei and Chen, 2002). In this material, when the intermittent drying is applied, cracking of the grain is avoided, because internal moisture gradient is reduced and energy efficiency is erased because time of heat applying is reduced, too.

The aim of this research was to study the effect on moisture content of applying a tempering time to the branches after the sapecado stage. If an appropriate moisture distribution is obtained, energy saves could be obtained in the drying stage.

II. MATERIAL AND METHODS

A. Material

Branches of yerba maté (*Ilex paraguarienses* Saint Hilaire) were used as test material. They were obtained at the outlet of the sapecador. Measures were made in three industrial factories between April and August/2008.

B. Methods

Four series of measurements were made:

1. *Study of moisture migration in different branches*: Branches of different shapes and sizes were used. They were put into an isolated container in order to form a bed. One branch was taken after a certain

time (0, 10, 20, 30, 45, 60, 90, 120, 210 y 300 min), then, the leaves were separated from the twigs and put into a hermetic container in order to determine moisture content. Eight series of measures were carried out.

2. *Determination of moisture content at different parts of a branch*: Branches with at least 4 sub-ramifications were used. In each sub-ramification, leaves were separated from twigs, and put into a hermetic containers in order to determine moisture content. Eight series of measures were carried out.
3. *Study of moisture migration in a single branch*: Branches, with at least 5 sub-ramifications, were used. They were put into an isolated container and they were taken after certain time (0, 10, 20, 30 and 1000 min, considering time=infinite). In each sub-ramification, leaves were separated from twigs and put into a hermetic container in order to determine moisture content. Thirty series of measures were carried out.
4. *Weight losses of branches during the tempering time*: Branches of different shapes and sizes were taken and put into a container. The weight of each branch was measured at 0, 5, 10, 15, 20 and 30 min. Sixteen series of measures were carried out with branches with leaves and two without leaves.

C. Moisture content

Moisture content was determined by drying the sample in an oven at 103 ± 2ºC until a constant weight was reached. It took about 6 h (IRAM 20503, 1995).

III. RESULTS AND DISCUSSION

A. Study of moisture migration in different branches

A regression analysis was made, considering the variation of moisture content in leaves and twigs during the tempering time. A significative fit level was reached when some data were rejected. The leaves had an intercept value of 21.19 % (wb) and a slope of 0.081 kg/(100 kg.min) (increase of moisture), while in twigs, they were 57.20 % (wb) and -0.0160 kg/(100 kg.min) (loss of moisture) (Fig. 1 and 2). In both cases, the confidence limits were very big.

The very high variation of data values could have probably appeared for many reasons. First of all, the low control of the equipment, specially the control of the size of the flame. This provokes different heat treatments for different branches. Second, the variability in sizes and shapes of branches makes the residence time vary between 2 and 4 minutes (Crotti *et al.*, 2002). This variation produces different moisture losses in the different branches. Third, the ratio between weight/ surface area is different for different leaves (Coelho *et al.*, 2002) and twigs (i.e. different diameters). This variation produces different heat and mass transfer in different branches.

To reduce the variation in moisture content between branches; the experiences, in a second step, were carried out with the different sub-ramifications of one branch. In this case, similar residence time and heat treatment can be assumed.

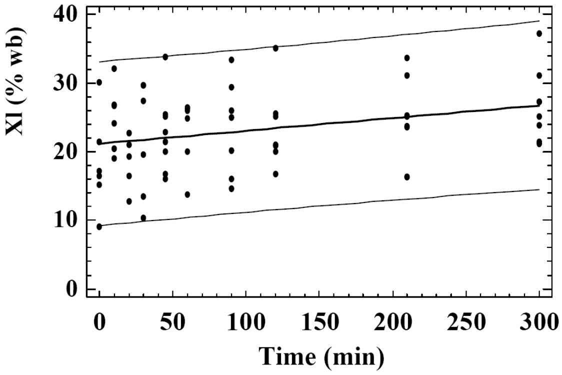

Figure 1. Moisture content variation of leaves during the tempering

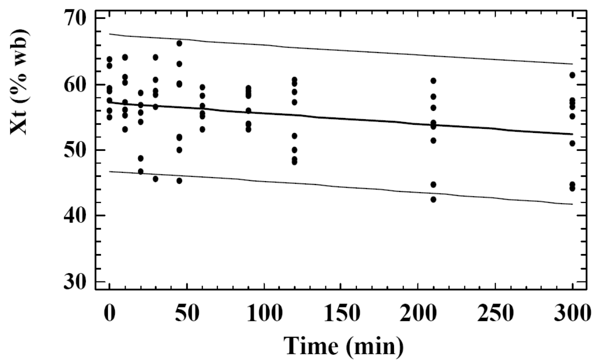

Figure 2. Moisture content variation of twigs during the tempering

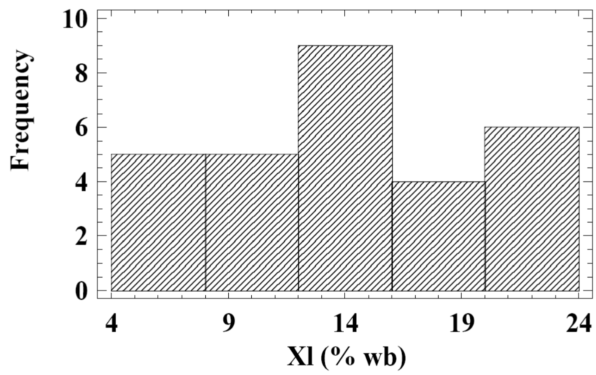

Figure 3. Moisture content distribution of leaves at the outlet of the sapecador (time=0)

B. Moisture distribution at different parts of a branch

In all cases, branches with at least 4 sub-ramifications, were used. Values which varied between 4.05 and 25.33 %(wb) were found. The variation coefficient was very high: 39.13%. Figure 3 shows the frequency distribution of moisture in leaves at the outlet of the sapecador. The experiences were carried out in one day. As can be observed, the distribution is very uniform. The variability between the sub-ramifications of the same branch was very high, too. A variation coefficient of 28.64% was found. Considering that the sub-ramifications of the same branch have the same residence time, this variation can only be found if they have different exposures when the branch crosses the flame. This fact produces a different heat treatment and consequently, different degrees of moisture in the branches.

C. Moisture migration in a single branch

In all cases, branches with at least 5 sub-ramifications were used. Significative differences in moisture content of leaves were found at different times (0, 10, 20, 30 and 1000 min) , with $P<10^{-4}$. (Fig. 4). Mean values were 17.27% (wb) at time= 0 min and 22.75% (wb) at time= 30 min. The mean increase of leaves moisture content was 5.48% (wb) (or 8.60 kg of water/100 kg of dry solid). In twigs, the differences in moisture content were not statistically significative (Fig. 5). The high variability in moisture content is probably the reason of this result. Confidence limits of moisture content, in both materials, were minor than ± 2% (wb). This value is quite different than that found in different branches (± 10%).

D. Weight losses of branches

During the tempering time, weight losses of branches, due to moisture evaporation, were detected. The percentage of the weight losses is shown in Fig. 6. After 30 min, the loss reached 3.3 % (wb) (or 5.17 kg water/

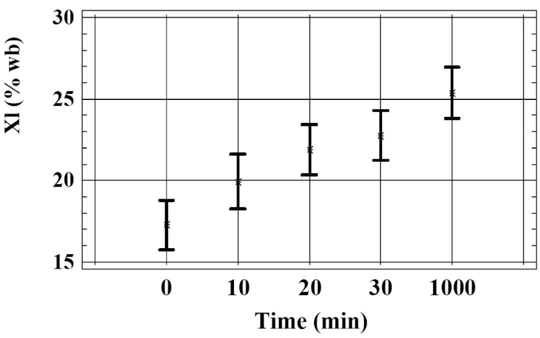

Figure 4. Moisture content variation of leaves from one branch during the tempering

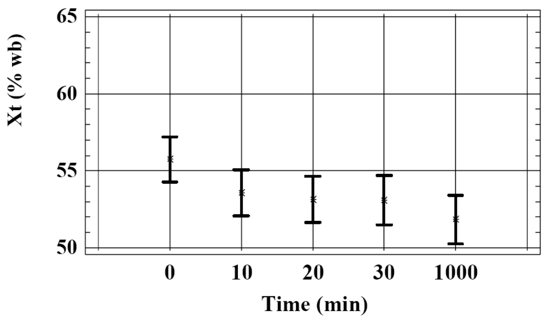

Figure 5. Moisture content variation of twigs from one branch during the tempering

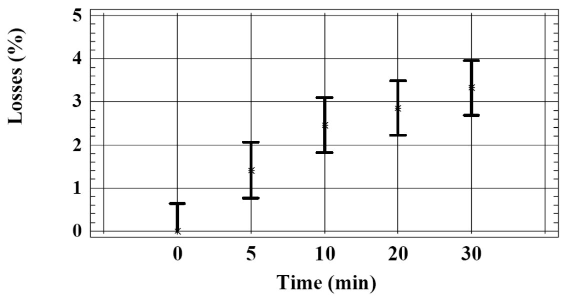

Figure 6. Weight losses of branches during the tempering

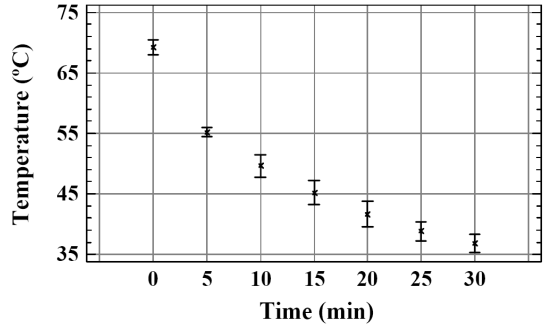

Figure 7. Temperature variation in the bed of branches during the tempering

100 kg of dry solid). When the experiences with branches without leaves were carried out, the losses were lower (2.4 % after 30 min).

Temperature variation in the bed, during the tempering time, was similar in all experiences. It varied between 69ºC at time=0 min to 37ºC after 30 min (Fig. 7).

E. Energy aspects

Energy balance was carried out in order to determine the percentage of heat losses during the tempering. It was carried out considering mean values of temperature and a tempering time of 30 min. Energy balance can be expressed as:

Heat transfer from the solids (Et)	=	
Energy used to evaporate water (Eu)	+	Heat losses (El)

The balance was carried out with 100 kg of dry solid. Et was calculated considering the specific heat of the branches and the difference in temperature between 69 and 37ºC. Specific heat of the branches was calculated using the equation reported by Schmalko *et al.* (1996), for leaves and twigs, separately. They were 2.20 kJ/kgºC for leaves and 3.11 kJ/kgºC for twigs. In 100 kg of dry solid there are 66.90 kg of dry leaves and 33.10 kg of dry twigs (Schmalko, 2005). Considering their moisture contents there are 80.87 kg of leaves and 75.16 kg of twigs. Et is calculated with the following equation:

$$Et = 80.87g*2.20\ (kJ/kgºC)*(69-37)ºC + 75.16kg*3.11\ (kJ/kgºC)*(69-37)ºC = 13173\ kJ$$

As it was experimentally determined, in 100 kg of dry solid, 5.17 kg of water was evaporated. Considering that the latent heat at 53ºC is 2366 kJ/kg (Schmalko *et al.*, 1998), energy used to evaporate the water is:

Eu= 5.17kg*2380 (kJ/kg) = 12305 kJ ,

and the heat losses are:

El= Et – Eu = 13173 kJ - 12305 kJ= 868 kJ

It represents only the 6.6% of Et, and it can be considered a low value (Kudra, 2004).

IV. CONCLUSIONS

When moisture of leaves and twigs were determined when a tempering time was applied to branches of yerba maté after the sapecado stage, an important water migration from twigs to leaves was found. Simultaneously, weight losses, due to moisture evaporation, were found.

Great variability in moisture of leaves and twigs was found after the sapecado stage. This variability could probably be due to different shapes and sizes of the branches and different exposures when the branch crossed the flame. A variation coefficient of 39.13% in leaves moisture was found at the outlet of the sapecador.

A tempering time of 30 min to the branches at the outlet of the sapecador should be applied. In this period the loss of moisture in the bed was 5.17 kg of water/100 kg of dry solid. A migration of 8.60 kg of water/100 kg of dry solid from twigs to leaves was also produced in this tempering time. The migration would reduce the drying time at the drying step, improving the energy efficiency. In this period, bed temperature decreased from 69 to 37ºC and most of the energy was used to evaporate the water (93.4 %).

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